GEOLOGY AND HYDROGEOLOGIC CONDITIONS OF THE SAN GERMÁN GROUND-WATER CONTAMINATION SITE, SOUTHWESTERN PUERTO RICO

Administrative Report

science for a changing world

Report for the U.S. Environmental Protection Agency

Geology and Hydrogeologic Conditions of the San Germán Ground-Water Contamination Site, Southwestern Puerto Rico

By Jesús Rodríguez-Martínez and Fernando Gómez-Gómez

Administrative Report

U.S. Department of the Interior
U.S. Geological Survey

Contents

Figures

Attachments

Geology and Hydrogeologic Conditions of the San Germán Ground-Water Contamination Site, Southwestern Puerto Rico

By Jesús Rodríguez-Martínez and Fernando Gómez-Gómez

Introduction

The U.S. Environmental Protection Agency (USEPA) is in the process of identifying the potential source(s) of chlorinated volatile compounds detected in municipal supply wells that are part of the San Germán Urbano water-supply system of the Puerto Rico Aqueduct and Sewer Authority (PRASA). In January 2007, the wells Lola Rodríguez de Tió 1, Lola Rodríguez de Tió 2, and Retiro were closed due to tetrachloroethylene (TCE) concentrations in ground water exceeding the Maximum Contaminant Level (MCL) of TCE. The MCL for TCE for drinking water established by the USEPA is 0.005 milligrams per litter (U.S. Environmental Protection Agency, 2007). The wells are located in the Río Guanajibo floodplain as shown in figure 1.

In order to identify the potential source(s) of the contaminant, the USEPA requested the U.S. Geological Survey (USGS) to prepare a report identifying the geologic and hydrogeologic conditions of the San Germán study area. The USGS was directed to include the following items: (1) identify the aquifer(s) within the study area and provide all relevant information describing the geology and hydrology of the study area (aquifer depth and thickness, lithologic composition, whether confining or water-table conditions are present, and ground-water flow direction(s)); (2) identify main recharge and discharge areas of the aquifer and potential contaminant source areas; (3) provide information on all drinking water wells within the study area including lithologic and well construction logs; and (4) identify potential data gaps needed to locate the contaminant source(s).

The area under investigation is located in the municipio of San Germán in southwestern Puerto Rico. The study area lies within the eastern part of the Río Guanajibo floodplain (fig. 1), which is bounded to the north and south by highlands of predominantly igneous rocks and serpentinite. The land-surface elevation of the floodplain within the study area ranges from about 157 feet above mean sea level in the eastern margin to about 98 feet above mean sea level in the western part. The long-term mean annual rainfall for 25 years of record (1948 to 1973) is 57.43 inches at the National Weather Service station, San Germán 4 (http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliMAIN.pl?pr8757). Minimum monthly rainfall typically occurs in February (long-term average of 1.70 inches) and maximum monthly rainfall occurs in September (long-term average of 9.21 inches). The mean annual temperature at this station for the same period of record indicates a maximum annual average temperature of 89.5 degrees Fahrenheit (°F) and a minimum annual average of 64.8 °F. Long-term temperature data indicate that the highest monthly average temperature occurs in July (91.5 °F) and the minimum monthly average occurs in February (60.4 °F).

Geology

The geologic units exposed in the study area or presumed to lie in the subsurface are from oldest to youngest: Serpentinite or serpentinized peridotite of late Jurassic and early Cretaceous age or older; the Mariquita Chert of late Jurassic and early Cretaceous with rare amygdular basalt and silicified limestone; the Sabana Grande Formation of late Cretaceous age consisting mainly of andesitic tuff and conglomerate with minor basaltic lava and breccia; an unnamed unit of altered volcanic rocks of presumably Cretaceous age; and alluvium of Quaternary age (Volckmann, 1984). The sequence of late Jurassic and early Cretaceous rocks are described as undifferentiated in figure 2. The late Jurassic and Cretaceous rocks in the study area have been highly folded and faulted.

The alluvial deposits in the Río Guanajibo valley are made up of sand, clay, and gravel (Volckmann, 1984). Depth to the rock basement within the valley (thickness of the alluvium) is generally less than 100 feet, as determined from examination of available water well lithologic logs and data from Colón-Dieppa and Quiñones-Márquez (1985) (see attachment 1 for lithologic logs for six wells within and near the study area).

Hydrogeology

The aquifer within the study area is part of the Río Guanajibo alluvial valley aquifer located in southwestern Puerto Rico. The aquifer is contained predominantly within the poorly to moderately consolidated deposits of sand and gravel of alluvial origin. The colluvial deposits, because of their higher clayey and silty content, are less permeable and, thus, poor water-bearing units. The ground-water-bearing potential of the underlying rocks of late Jurassic and Cretaceous age is minimal, except where these units may be highly fractured and weathered.

Ground-water flow occurs under semi-confined and unconfined conditions. Unconfined conditions predominantly occur in the eastern part of the study area, including the suburban areas of San Germán, where the alluvium is relatively thin and thickness of surficial clay and silt is slight. The occurrence of semi-confining conditions within the unconsolidated deposits generally increases west of the town of San Germán as the depth to basement rock and the thickness of both surficial and subsurface clay and silt strata increase.

Ground-Water Flow and Hydraulic Properties

The general ground-water flow direction in the study area can be inferred from the potentiometric-surface map developed by the USGS as part of an assessment of the water resources of the Río Guanajibo valley conducted during 1979 and 1980 and shown on figure 2 (Colón-Dieppa and Quiñones-Márquez, 1985). The potentiometric-surface map from Colón-Dieppa and Quiñones-Márquez (1985) was developed to show the regional ground-water surface gradient in the Río Guanajibo alluvial valley. The drainage of the aquifer by the Río Guanajibo should be similar to conditions reported by Puig and Rodríguez (1990) (attachment 2 presents a section of their plate 1 map) in the Río Gurabo alluvial valley where relatively impermeable bedrock units bound the aquifer along its longitudinal axis. In these hydrogeologic conditions the aquifer is drained by the river and the potentiometric-surface contours form a pronounced v-shape upstream. In general, the predominant movement of ground water in the Río Guanajibo alluvial valley upstream from San Germán should be preferentially toward the course of the Río Guanajibo (fig. 2). In addition, the tributary streams to the Río Guanajibo likely act as aquifer drains. Depth to water ranges from stream level at the Río Guanajibo to about 15 feet at higher land-surface elevations.

Estimates of the transmissivity of the aquifer within the study area are scarce. Data available indicate that transmissivity is significantly less than in the lower reaches of the Río Guanajibo alluvial valley aquifer due to the reduced thickness of the unconsolidated deposits, and may be in the range of 500 to 1,000 feet squared per day (ft^2/d) (Colón-Dieppa and Quiñones-Márquez, 1985; R. Anders, U.S. Geological Survey, written commun., 1968). This range would be equivalent to hydraulic conductivity values in the range of 5 to 10 feet per day (ft/d). The higher values are in the alluvial sands and gravels in the narrows near San Germán.

Annual net recharge to the aquifer within the study area may be less than 1 inch per year (about 0.77 inch per year) as estimated from 7Q10 values obtained in the vicinity of Sabana Grande to San Germán from studies conducted in the early 1990s (Santiago-Rivera, 1996; 7Q10 is defined as streamflow that occurs over 7 consecutive days and has a 10-year recurrence interval period, or a 1 in 10 chance of occurring for 7 consecutive days in any one year) (location of streamflow stations are presented in attachment 3). Daily streamflows in the 7Q10 range are general indicators of prevalent drought conditions, which normally cover large areas. The 7Q10 values are also used by the Commonwealth of Puerto Rico for regulating water withdrawals and discharges into streams. The 7Q10 flows estimated by Santiago-Rivera (1996) are fairly close to the Q_{98} flow-duration characteristic (flow equaled or exceeded 98 percent of the time). The Q_{98} flow duration statistic has been used as a conservative estimate of net ground-water recharge (Gómez-Gómez and others, 2001). The net recharge to the aquifer within the study area is entirely from infiltration of rainfall.

Discharge from the aquifer within the study area is to public-supply wells, seepage to the Río Guanajibo, and evapotranspiration. Water for human use is provided by public-supply sources operated by the Puerto Rico Aqueduct and Sewer Authority (PRASA), but as of December 2006, the PRASA wells are inactive. However, withdrawals from public-supply wells in the vicinity of San Germán may have been as much as 430,000 gallons per day from the PRASA public-supply water wells Lola Rodríguez de Tió 1, Lola Rodríguez de Tió 2, and Retiro (W. Molina, U.S. Geological Survey, written commun., 2007). The PRASA wells located within the study area are presented in attachment 4. As of 2006, there is no reported ground-water withdrawal for agricultural use in the study area and there are no known privately owned wells within the study area for domestic use.

The source of some Retiro public-supply well water, if not all, may be induced streamflow from the Río Guanajibo, due to its proximity to the stream and limited aquifer storage. The same conditions apply to the now inactive Lola Rodríguez de Tió 1 and 2 public-supply wells. According to a PRASA field technician, these two public-supply wells were taken out of service because of very low yields. Possibly, the yield to these wells declined as a result of lowering of the streambed as part of the flood channelization works in the Rio Guanajibo, draining permeable sand and gravel deposits near the wells, thus reducing the transmissivity in the saturated zone. The relation between induced streamflow and aquifer storage for wells near streams is conceptualized in figure 3 (adapted from Alley and others, 1999). Withdrawals from wells in close proximity to streams initially come from bank storage or the regional ground-water flow system, but with increasing pumping time, induced streamflow becomes the primary source of water to the wells (Alley and others, 1999; Jenkins, 1970).

Ground-Water Contamination

Tetrachloroethylene (TCE) has been detected in water from some wells in the Río Guanajibo valley aquifer. Delineation of the possible extent and direction of movement, as well as determination of the probable source of the contaminant were not made due to the limited data available. Streamflow seepage data along the Río Guanajibo in conjunction with surface-water samples may be used to identify sites along the stream channel where contaminants may originate. Current water-quality data for suspect contaminants in the Río Guanajibo are not available.

Public-supply wells, where water quality is of concern for the USEPA, and the status of operation of these wells are listed below (the locations of these wells are shown on the map in attachment 4). The exact date of cessation of withdrawals from these wells is not known.

1. Lola Rodríguez de Tió 1- inactive during the past year
2. Lola Rodríguez de Tió 2- inactive during the past year
3. Retiro- inactive

Data needed to define source(s) of contamination are:

- Better definition of the potentiometric surface than the one that currently exists, both aerially and vertically,
- Detailed lithologic logs of wells near the PRASA wells, and
- Water-quality data (for suspect contaminants) collected during low-flow conditions along the Río Guanajibo.

References Cited

Alley, W.M., Reilly, T.E., and Franke, O.L., 1999, Sustainability of ground-water resources: U.S. Geological Survey Circular 1186, 79 p.

Colón-Dieppa, Eloy, and Quiñones-Márquez, Ferdinand, 1985, A reconnaissance of the water resources of the Central Guanajibo valley, Puerto Rico: U.S. Geological Survey Water-Resources Investigations Report 82-4050, 47 p.

Gómez-Gómez, Fernando, Rodríguez-Martínez, Jesús, Santiago-Rivera, Luis, Oliveras-Feliciano, M.L., and Conde-Costas, Carlos, 2001, Surface-water, water-quality, and ground-water assessment of the municipio of Caguas, Puerto Rico, 1997-99: U.S. Geological Survey Water-Resources Investigations Report 00-4280, 42 p., 2 pls.

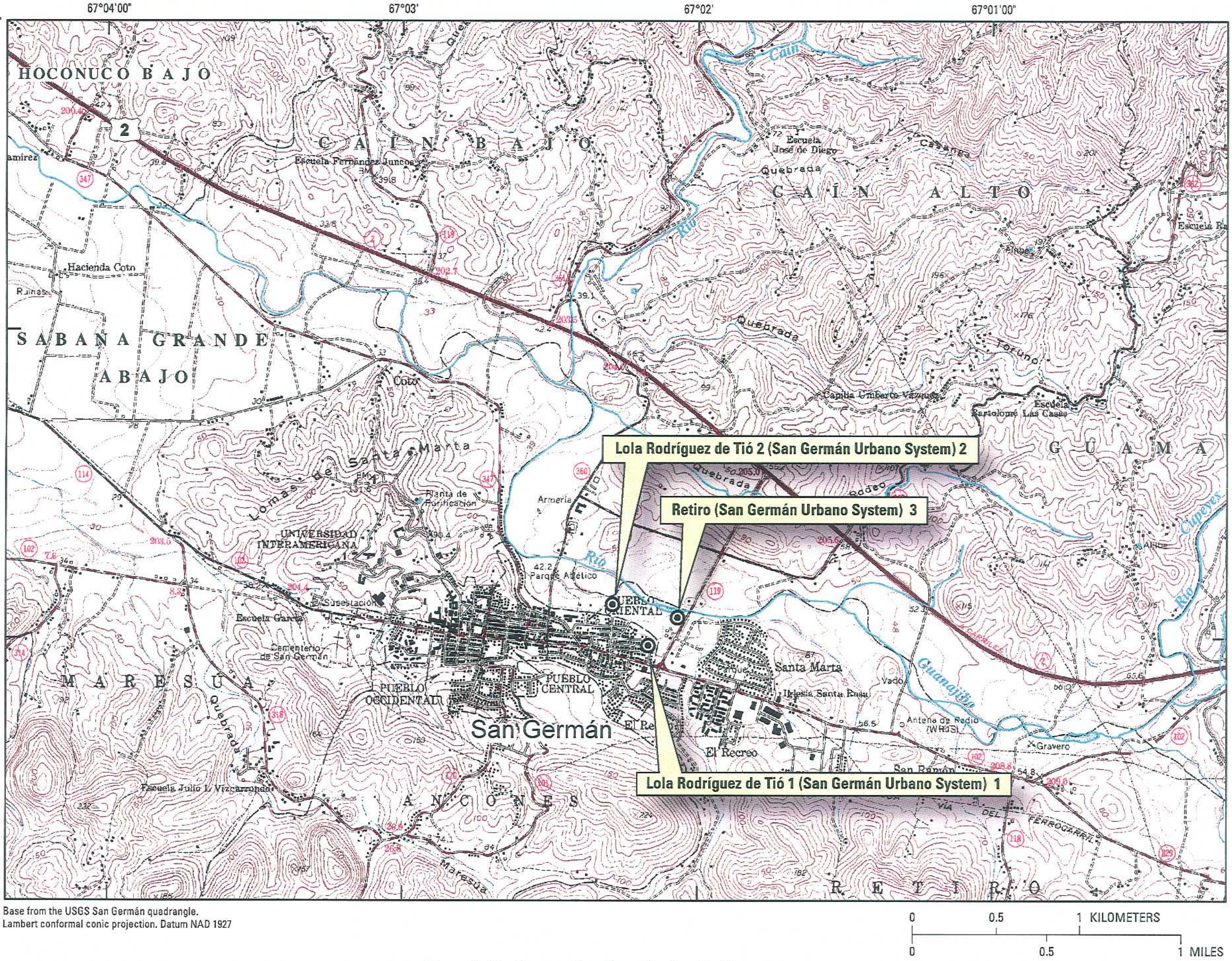
Jenkins, C.T., 1970, Computation of rate and volume of stream depletion by wells: U.S. Geological Survey Techniques of Water-Resources Investigations, Chapter D1, Book 4, Hydrologic Analysis and Interpretation, 17 p.

Puig, J.C., and Rodríguez, J.M., 1990, Potentiometric surface of the alluvial aquifer and hydrologic conditions near Gurabo and Juncos, Puerto Rico, March 1988: U.S. Geological Survey Water-Resources Investigations Report 90-4059, 2 sheets.

Santiago-Rivera, Luis, 1996, Low-flow characteristics at selected sites on streams in southern and western Puerto Rico: U.S. Geological Survey Water-Resources Investigations Report 95-4147, 46 p.

U.S. Environmental Protection Agency, 2007, Drinking water contaminants, List of contaminants and their MCLs: accessed July 2007 at http://www.epa.gov/safewater/contaminants/index.html#organic

Volckmann, R.P., 1984, Geologic map of the San Germán quadrangle, southwest Puerto Rico: U.S. Geological Survey Miscellaneous Investigations Series Map I-1558, 1 sheet.



Base from the USGS San Germán quadrangle.
Lambert conformal conic projection. Datum NAD 1927

Figure 1. Study area, San Germán, Puerto Rico.

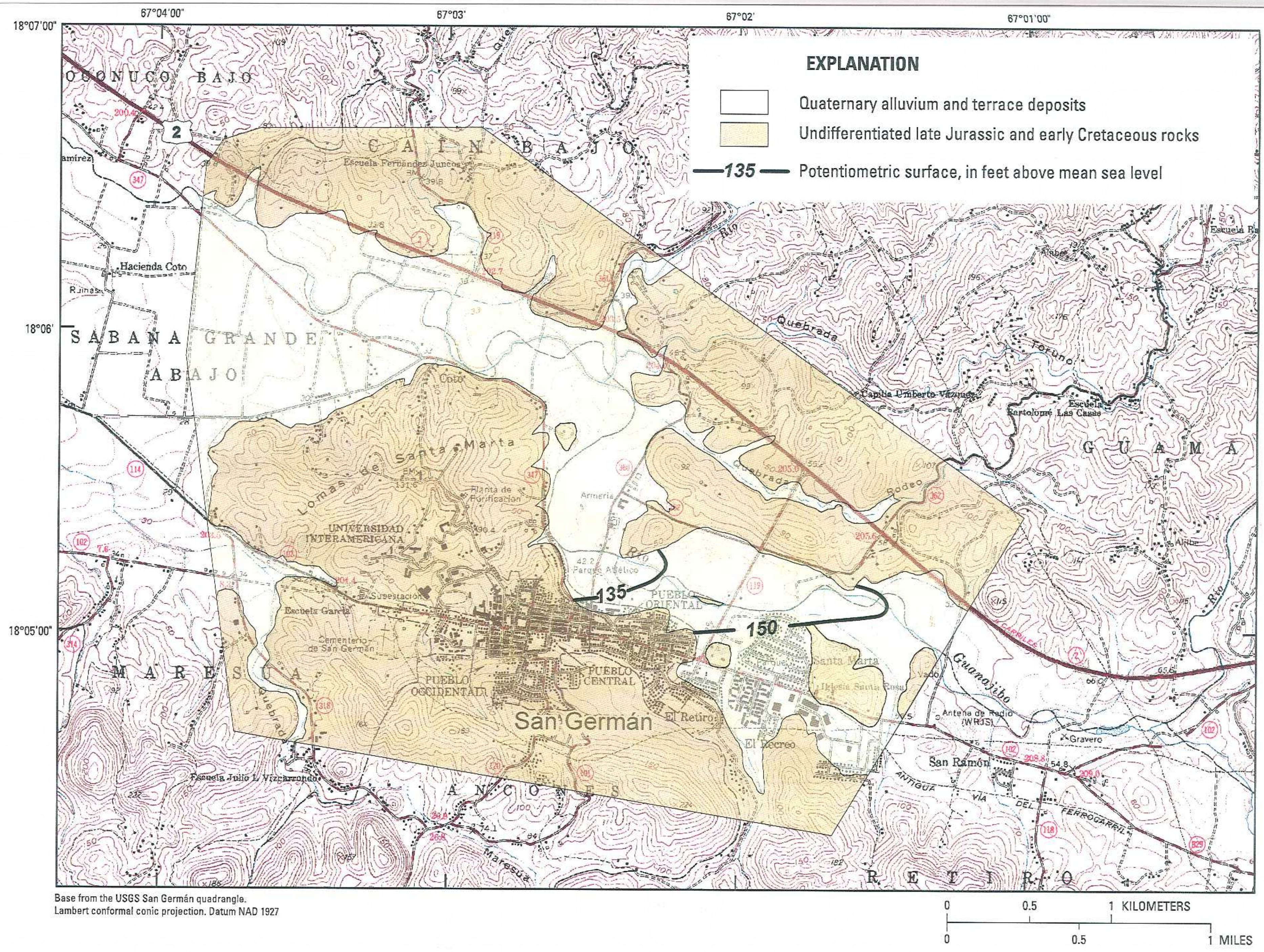


Figure 2. Generalized geology and configuration of the potentiometric surface in the Río Guanajibo valley near San Germán. The potentiometric contours shown take into consideration the effectiveness of the Río Guanajibo on aquifer drainage (modified from Colón-Dieppa and Quiñones-Márques, 1985).

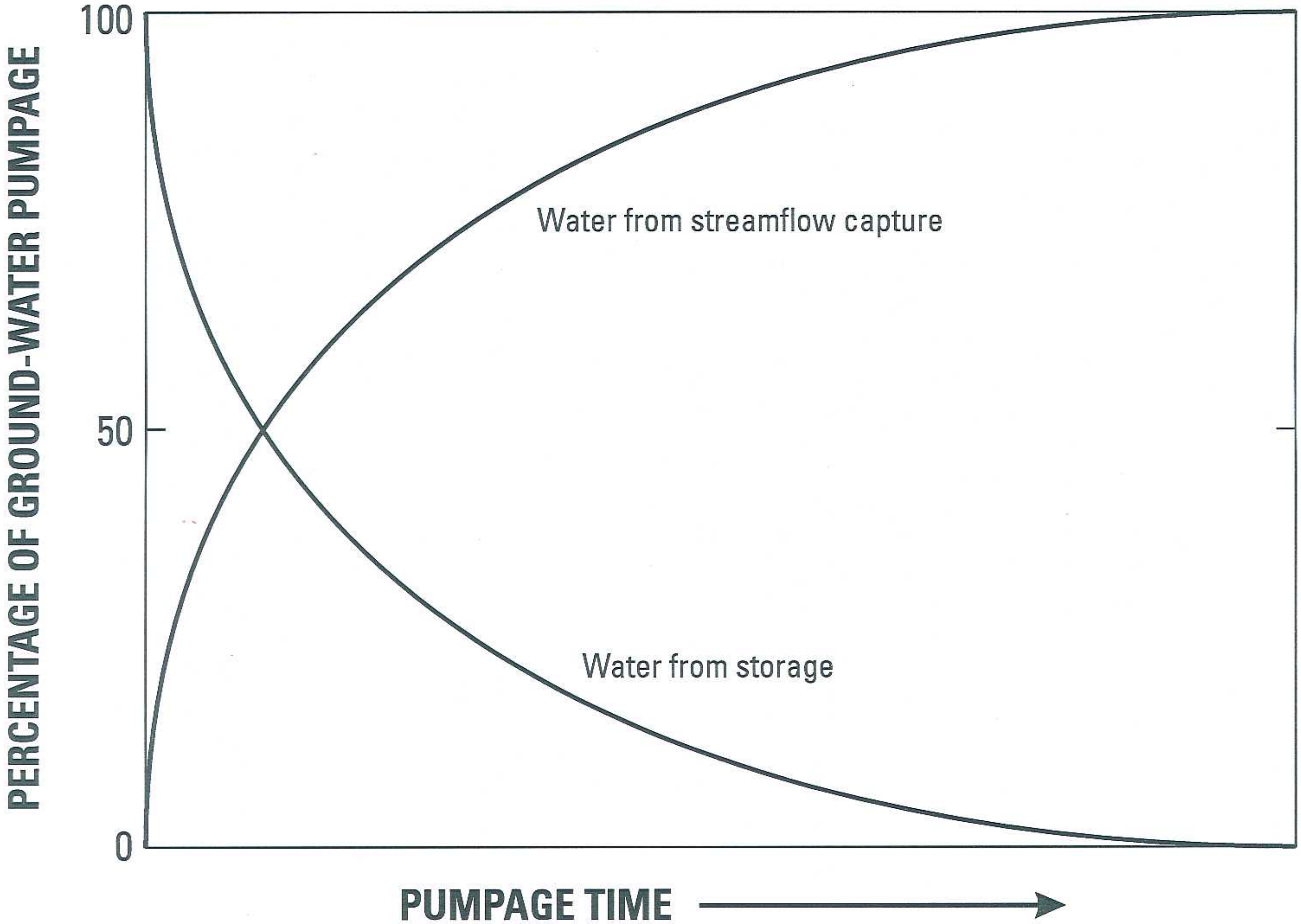


Figure 3. How with time the principal source of water can change to a well from ground-water storage to capture of streamflow (adapted from Alley and others, 1999).

Attachment 1. Lithologic logs of wells within and near the study area.

<table>
<tr><td colspan="2">Name of well: PRASA Río Guanajibo   Hole depth: 73 feet
Latitude: 180518   Well depth: 40 feet
Longitude: 670229
Date of construction: July 1, 1961
USGS File Code: 05-67.02-07-66</td></tr>
<tr><th>Depth interval, in feet</th><th>Lithologic description</th></tr>
<tr><td>0-3</td><td>Soil- clayey and silty with organic material (vegetative remains)</td></tr>
<tr><td>3-7</td><td>Sand, loose, mostly coarse to very coarse grained, predominantly lithic</td></tr>
<tr><td>7-15</td><td>Claystone- medium brown, soft to moderately indurated, with rock fragments (probably colluvium)</td></tr>
<tr><td>15-19</td><td>Claystone- generally as above</td></tr>
<tr><td>19-24</td><td>Claystone-siltstone with decomposed rock fragments *</td></tr>
<tr><td>24-37</td><td>Claystone, yellow, moderately indurated*</td></tr>
<tr><td>37-40</td><td>Volcanic rocks- gray, altered</td></tr>
<tr><td colspan="2">* May have resulted from weathering of basement rock or washed down from the highlands as colluvium.</td></tr>
</table>

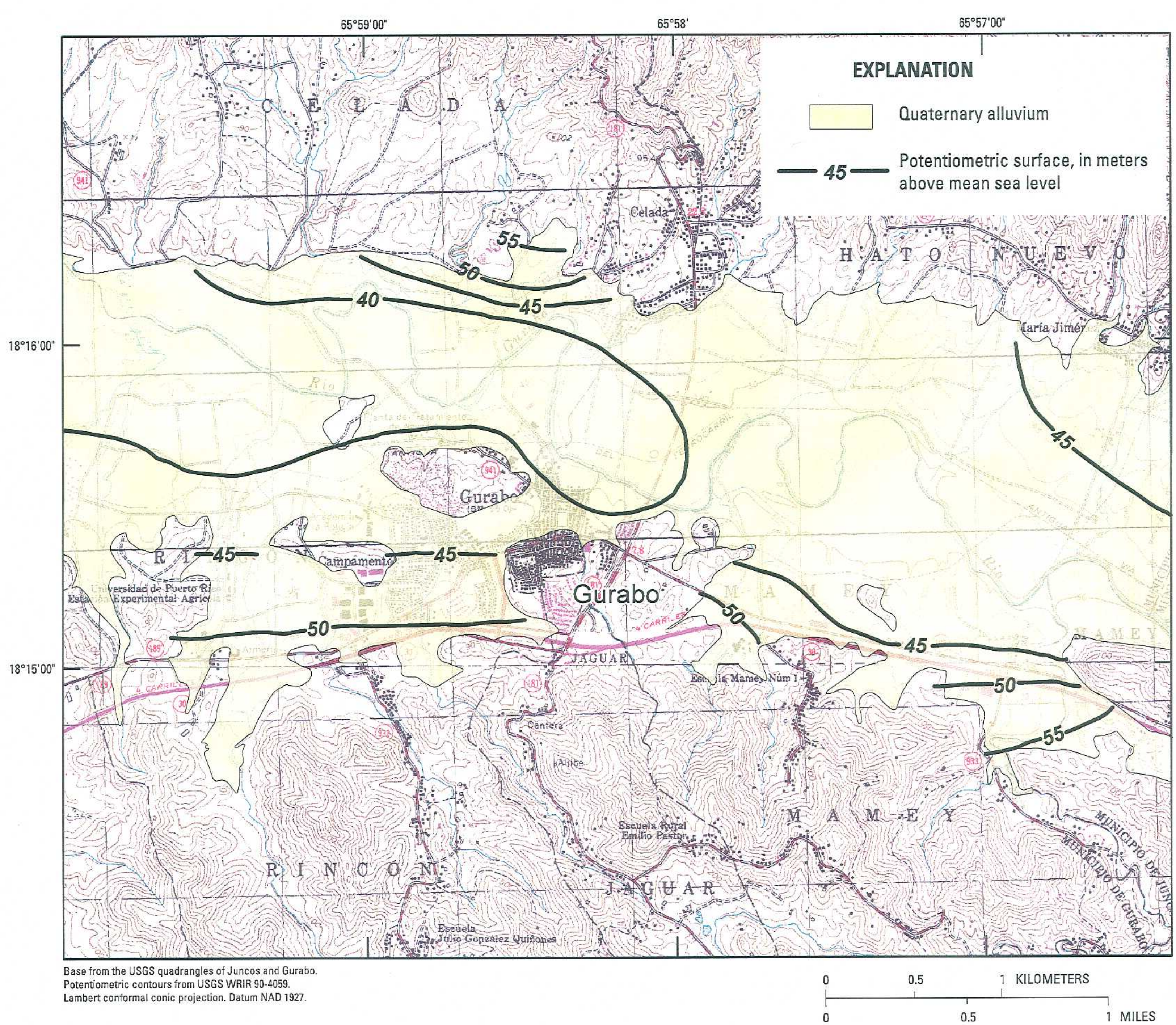
<table>
<tr><td colspan="2">Name of well: Central Eureka-1   Hole depth: 180 feet
Latitude: 180729   Well depth: 100 feet
Longitude: 670706
Date of construction: 1937
USGS File Code: 07-67.07-01-59</td></tr>
<tr><th>Depth interval, in feet</th><th>Lithologic description</th></tr>
<tr><td>0-40</td><td>Gravel-clayey</td></tr>
<tr><td>40-42</td><td>Clay-yellow, soft to moderately indurated</td></tr>
<tr><td>42-60</td><td>Sand and Gravel- clean (with minimum or no clay)</td></tr>
<tr><td>60-180</td><td>Clay-gray colored</td></tr>
</table>

Name of well: PRASA Santa Marta Latitude: 180537 Longitude: 670239 Date of construction: May 1961 USGS File Code: 05-67.02-08-34	Hole depth: 101 feet Well depth: not available
Depth interval, in feet	Lithologic description
0-1	Soil- dark brown, with vegetative remains
1-5	Claystone and Siltstone- Yellow
5-11	Volcanic rock-very altered (described by driller as sandy and decomposed rock)
11-94	Shale-because of the underlying serpentinite, this “shale is interpreted as a lateritic clay (iron-aluminum rich) known to be the residual of the weathering product of the serpentinite, so common in the San German area.
94-101	Serpentinite- (described by driller as red granite)- is the prevalent basement rock in the vicinity and weathers to a reddish color

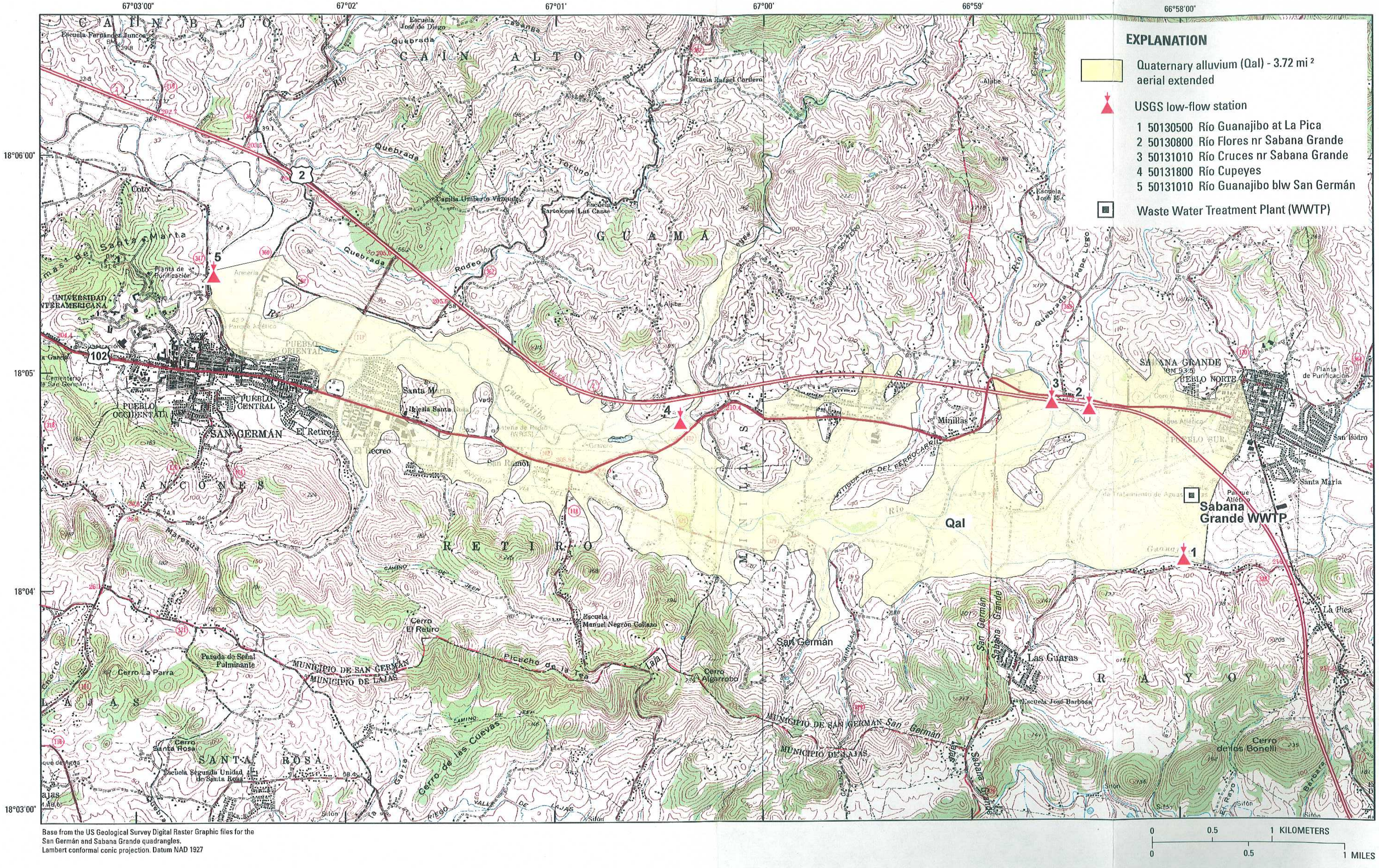
Name of well: Planta de Hielo (Ice Plant) Latitude: 180507 Longitude: 670232 Date of construction: 1948 USGS File Code: 05-67.02-01-85	Hole depth: 60 feet Well depth: 20 feet
Depth interval, in feet	Lithologic description
0-5	Clay-brown and yellow
5-10	Gravel
10-60	Rock-green (maybe interpreted as serpentinite)

Name of well: PRASA Caín Bajo 2 Latitude: 180555 Longitude: 670241 Date of construction: November 1961 USGS File Code: 05-67.02-06-14	Hole depth: 65 feet Well depth: 40 feet
Depth interval, in feet	Lithologic description
0-3	Soil-silty and clayey, with vegetative remains
3-10	Gravel (dry)
10-30	Sand and gravel
30-65	Basement rock described as dark green-can be interpreted as serpentinite that outcrops in the surroundings

Name of well: PRASA Rodríguez Tió Latitude: 180507 Longitude: 670206 Date of construction: USGS File Code: 05-67.02-11-100	Hole depth: 100 feet
Depth interval, in feet	Lithologic description
0-6	Soil-dark brown, with organic material (vegetative remains)
6-10	Boulders – may be interpreted as chert and/or silicified limestone boulders washed down from hills in the south, maybe part of colluvium deposits; occurring as landslide deposits in the highlands south of the town of San Germán)
10-30	Brown limestone with boulders- moderately to strongly silicified limestone and chert boulders with the same origin as above
30-100	Serpentinite-described by driller as hard blue rock, predominant rock outcrop in the vicinity

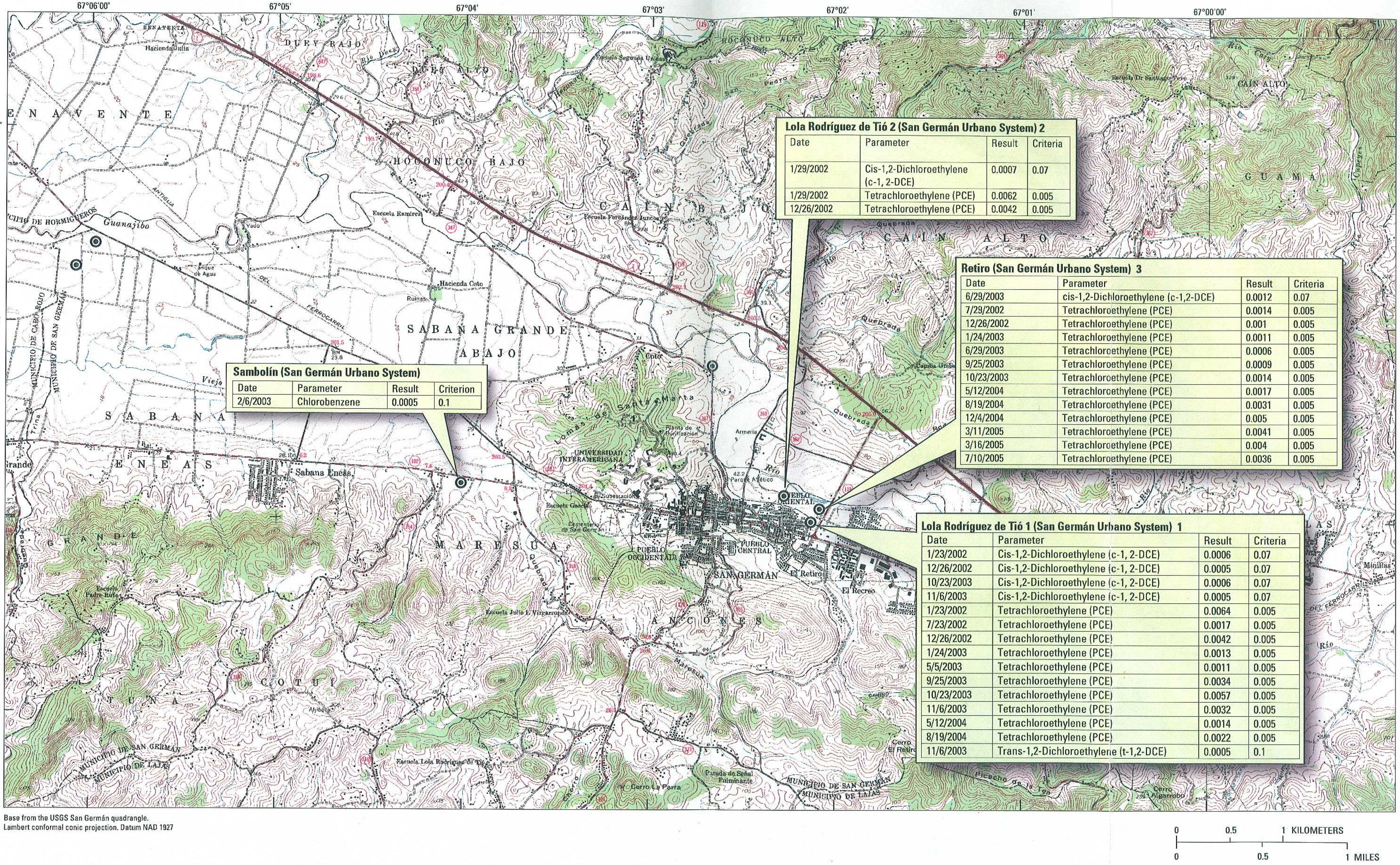


Attachment 2. Section of potentiometric-surface map of the Río Gurabo valley in vicinity of the Gurabo Agricultural substation (modified from Puig and Rodríguez, 1990).



Base from the US Geological Survey Digital Raster Graphic files for the San Germán and Sabana Grande quadrangles.
Lambert conformal conic projection. Datum NAD 1927

Attachment 3. Extent of unconsolidated deposits in the Río Guanajibo Valley and locations of stream low-flow stations



Lola Rodríguez de Tió 2 (San Germán Urbano System) 2

Date	Parameter	Result	Criteria
1/29/2002	Cis-1,2-Dichloroethylene (c-1, 2-DCE)	0.0007	0.07
1/29/2002	Tetrachloroethylene (PCE)	0.0062	0.005
12/26/2002	Tetrachloroethylene (PCE)	0.0042	0.005

Retiro (San Germán Urbano System) 3

Date	Parameter	Result	Criteria
6/29/2003	cis-1,2-Dichloroethylene (c-1,2-DCE)	0.0012	0.07
7/29/2002	Tetrachloroethylene (PCE)	0.0014	0.005
12/26/2002	Tetrachloroethylene (PCE)	0.001	0.005
1/24/2003	Tetrachloroethylene (PCE)	0.0011	0.005
6/29/2003	Tetrachloroethylene (PCE)	0.0006	0.005
9/25/2003	Tetrachloroethylene (PCE)	0.0009	0.005
10/23/2003	Tetrachloroethylene (PCE)	0.0014	0.005
5/12/2004	Tetrachloroethylene (PCE)	0.0017	0.005
8/19/2004	Tetrachloroethylene (PCE)	0.0031	0.005
12/4/2004	Tetrachloroethylene (PCE)	0.005	0.005
3/11/2005	Tetrachloroethylene (PCE)	0.0041	0.005
3/16/2005	Tetrachloroethylene (PCE)	0.004	0.005
7/10/2005	Tetrachloroethylene (PCE)	0.0036	0.005

Sambolín (San Germán Urbano System)

Date	Parameter	Result	Criterion
2/6/2003	Chlorobenzene	0.0005	0.1

Lola Rodríguez de Tió 1 (San Germán Urbano System) 1

Date	Parameter	Result	Criteria
1/23/2002	Cis-1,2-Dichloroethylene (c-1, 2-DCE)	0.0006	0.07
12/26/2002	Cis-1,2-Dichloroethylene (c-1, 2-DCE)	0.0005	0.07
10/23/2003	Cis-1,2-Dichloroethylene (c-1, 2-DCE)	0.0006	0.07
11/6/2003	Cis-1,2-Dichloroethylene (c-1, 2-DCE)	0.0005	0.07
1/23/2002	Tetrachloroethylene (PCE)	0.0064	0.005
7/23/2002	Tetrachloroethylene (PCE)	0.0017	0.005
12/26/2002	Tetrachloroethylene (PCE)	0.0042	0.005
1/24/2003	Tetrachloroethylene (PCE)	0.0013	0.005
5/5/2003	Tetrachloroethylene (PCE)	0.0011	0.005
9/25/2003	Tetrachloroethylene (PCE)	0.0034	0.005
10/23/2003	Tetrachloroethylene (PCE)	0.0057	0.005
11/6/2003	Tetrachloroethylene (PCE)	0.0032	0.005
5/12/2004	Tetrachloroethylene (PCE)	0.0014	0.005
8/19/2004	Tetrachloroethylene (PCE)	0.0022	0.005
11/6/2003	Trans-1,2-Dichloroethylene (t-1,2-DCE)	0.0005	0.1

Attachment 4. Puerto Rico Aqueduct and Sewer Authority wells in the study area (concentrations of selected contaminants in milligrams per liter (mg/L)).